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ICE - BREAKING BY EXPLOSIVES

6 DECEMBER 1966

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 66-229

ICE-BREAKING BY EXPLOSIVES

by

Robert M. Barash

ABSTRACT: Data are reported on the sizes of clearings broken in a lake ice sheet 20 to 30 inches thick, as a result of each of 45 explosions. The charge weights varied from 1 to 42 lbs, and the charge positions varied from 20 ft below to 2 ft above the ice layer.

UNDERWATER EXPLOSIONS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, SILVER SPRING, MARYLAND

 6 December 1966

ICE-BREAKING BY EXPLOSIVES

This report is a brief presentation of some experimental work which has previously been available only in classified form. Because of current interest in this work inside and outside the Laboratory, the unclassified aspects are given here.

The work was done in 1960 and was supported primarily by the Bureau of Naval Weapons under WepTask No. RUME-3-E-000/212-1/WF008-10-004, PA 002, Supporting Research in Underwater Explosives and Explosions, and was published in Confidential Report NOLTR 62-96.

E. F. SCHREITER
Captain, USN
Commander

C J Aronson
C. J. ARONSON
By direction

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ICE-BREAKING BY EXPLOSIVES

1. INTRODUCTION

1.1 An important problem in operations in the Arctic is the development of an effective method of clearing the pack ice. Explosives have been used, but no systematic study of the optimum charge size and charge depth has been carried out.

1.2 As an early step in exploring the effects of explosions in an ice-covered lake, measurements were taken of the areas in the ice sheet that were broken up and/or cleared by such explosions. The tests were conducted during January through March 1960 at Moonshine Lake in the Chippewa National Forest in Minnesota.

2. EXPERIMENTAL PROGRAM

2.1 Results of 45 explosions are reported here. This includes 8 charges with a nominal weight of 42 lbs, 20 eight-lb charges, and 17 one-lb charges. All were cast TNT spheres, except for 2 eight-lb and 3 one-lb HBX-3 spheres. All had pentolite boosters.

2.2 The charges were placed at various positions with respect to the ice sheet, ranging from 20 ft below to 2 ft above. The ice thickness varied from 20 to 30 inches during the course of the tests.

2.3 Figure 1 shows a sequence of photographs of the above-surface effects of an under-ice explosion. Typically, the shock wave pulse causes the ice layer to rise in the shape of a shallow dome, as in photograph (a). The effect of the bubble appears either before or after the dome begins to fall back, depending upon the depth of explosion. As the bubble reaches the surface, pieces of ice are thrown out, either mostly upward or mostly radially, depending upon the phase of the bubble motion at the time it vents.

2.4 The result is generally an area, more or less circular in shape, containing pieces of ice, the amount varying from 0 to 100% of the ice originally in the area, and their sizes varying from very small to about 10 ft long in some cases.

2.5 This broken-up area may contain a smaller area of open water containing no ice. In addition, in some cases there may be an outer perimeter at which a severe crack occurs, or within which the ice layer, although not broken into loose pieces, is permanently buckled.

2.6 An attempt was made after each shot to estimate the amount of ice which remained in or returned to the broken ice area, as a percentage of the volume of ice originally in the area. Also a classification of the sizes of the pieces was attempted. These data are available for most of the shots, but the estimates are so crude that they will be presented here only in a very simplified form. The broken ice area resulting from each shot will be described as containing either less or more than half its original volume of ice. In general, those holes in which most of the ice remains or returns contain a large proportion of large pieces of ice - that is, at least 3 ft long; and the converse is also true.

3. RESULTS

3.1 Tables 1, 2 and 3 list for the 42-lb, 8-lb, and 1-lb shots respectively, the three diameters discussed in Paragraphs 2.4 and 2.5, and the proportion discussed in Paragraph 2.6. The experimental variables listed in each table are charge depth, explosive composition, ice thickness, and water depth. It is felt that water depth may be a significant variable because of its effect on bubble migration. The water depth is the distance from the top of the ice layer to the bottom of the lake. The charge depth is measured from the top surface of the ice, positive downward. Thus a charge depth of d + 10 ft (where d is the ice thickness for a particular shot) indicates that the center of the charge is placed 10 ft below the bottom of the ice. A charge depth of -2 ft indicates that the center of the charge is 2 ft above the top of the ice. For charge depths of 0 and d, the charges were placed in hemispherical depressions in the top and bottom surfaces of the ice respectively. The charge depth of d/2 was obtained by filling and re-freezing the opening through which the charge was placed at a central position in the ice layer.

3.2 Figure 2 is a graph of the resultant hole radius as a function of the charge depth, for the three sizes of TNT charges. For each charge size, there appears to be an optimum charge depth - that is, the charge depth yielding the largest hole.

3.3 The optimum charge depth, and the corresponding hole radius, are both approximately proportional to the cube root of the charge weight. This is not surprising, in view of the following two well-established scaling laws for geometrically similar configurations, one relating to the shock wave, and the other to the bubble. First, the distance at which a given value of peak shock wave pressure occurs is proportional to the cube root of the charge weight; and second, the maximum bubble radius expected in free water is approximately proportional to the cube root of the charge weight, for shallow charge depths.

3.4 The peculiar shapes of these three curves can be shown to be related to the size and the dynamic state of the bubble at the time it vents, as a function of the depth of explosion. This suggests that the bubble plays a more important role than the shock wave in determining the size of the hole. This finding is supported by the greater hole sizes generally resulting from the use of HBX-3, an explosive producing a larger bubble than TNT.

TABLE 1. CLEARINGS BROKEN IN LAKE ICE BY EXPLOSION OF 42-LB CHARGES

Charge Depth Below Top of Ice (ft)	Expl. Comp.	Ice Thick-ness (in)	Water Depth From Top of Ice (ft)	Average Diameter of Open Water Area (ft)	Average Diameter of Broken Ice Area (ft)	More or Less Than Half of Original Ice Returned	Average Diameter of Buckling or Severe Crack (ft)
d+2.5*	TNT	24.5	48	40	49	less	--
d+2.75	TNT	28	50.4	27.5	51.5	less	--
d+5	TNT	24	36.5	49	49	less	--
d+5	TNT	29.5	30.9	0	61	less	--
d+6	TNT	30	25.8	0	53	less	--
d+8	TNT	29.5	46	0	53.5	more	--
d+10	TNT	25	50.5	0	52	more	--
d+17.22	TNT	25	57.9	0	42	more	--

*d = Ice thickness as given in col 3, and converted to ft

TABLE 2. CLEARINGS BROKEN IN LAKE ICE BY EXPLOSION OF 8-LB CHARGES

Charge Depth Below Top of Ice (ft)	Expl. Comp.	Ice Thick-ness (in)	Water Depth From Top of Ice (ft)	Average Diameter of Open Water Area (ft)	Average Diameter of Broken Ice Area (ft)	More or Less Than Half of Original Ice Returned	Average Diameter of Buckling or Severe Crack (ft)
-2	TNT	23	24.7	0	0	--	--
-1	TNT	23	24.7	0	0	--	--
-1	TNT	27	16.7	0	0	--	--
0	TNT	27	18.3	0	4.5	less	--
d*	TNT	25	33.9	0	25	less	--
d+0.27	TNT	26	15.4	0	23.5	more	--
d+1.45	TNT	25	33.9	3	32.5	more	--
d+1.45	TNT	26	17.2	0	32.5	more	--
d+2.9	TNT	22.5	40	12	34	less	--
d+2.9	HBX-3	29	27.8	0	41	less	--
d+4	TNT	24.5	27.3	0	31.5	more	--
d+5	TNT	23	32.2	0	28	more	--
d+5	TNT	25.5	24.8	0	27.5	more	--
d+7.5	TNT	29	27.8	0	15.25	less	27.25
d+10	TNT	20	33	0	15.25	more	--
d+10	TNT	20	33	0	18	more	--
d+13	TNT	29	35.2	0	18	less	25
d+16	TNT	28	32.5	0	17.75	less	--
d+20	TNT	27	60	4.5	10.5	less	--
d+20	HBX-3	29	66.3	0	23.75	less	--

*d = Ice thickness as given in col. 3, and converted to ft

TABLE 3. CLEARINGS BROKEN IN LAKE ICE BY EXPLOSION OF 1-LB CHARGES

Charge Depth Below Top of Ice (ft)	Expl. Comp.	Ice Thick-ness (in)	Water Depth From Top of Ice (ft)	Average Diameter of Open Water Area (ft)	Average Diameter of Broken Ice Area (ft)	More or Less Than Half of Original Ice Returned	Average Diameter of Buckling or Severe Crack (ft)
0	TNT	24	23.8	0	0	--	--
d/2*	TNT	24	26	0	3	less	--
d/2	TNT	27	16	0	3	less	--
d	TNT	22.5	26.8	0	13	more	--
d+1.45	TNT	25	24.2	0	16	more	--
d+1.45	HBX-3	30	18	0	7	less	20
d+2.5	TNT	22	43.3	3.5	3.5	less	15
d+2.5	HBX-3	29	19.2	0	6	less	19.5
d+4	TNT	30	67.3	0	3.75	less	11
d+5	TNT	23	35	0	7	less	20
d+5	HBX-3	23	31	0	8	more	25
d+5	TNT	26	20.3	0	3	more	14
d+5	TNT	30	67.3	1.75	1.75	less	14
d+6	TNT	30	64.7	0	4.5	less	--
d+7.5	TNT	29	30.8	0	1.5	more	--
d+10	TNT	27	32.5	0	0	--	--
d+11	TNT	29	65.3	0	0	--	--

*d = Ice thickness given in col. 3, and converted to ft

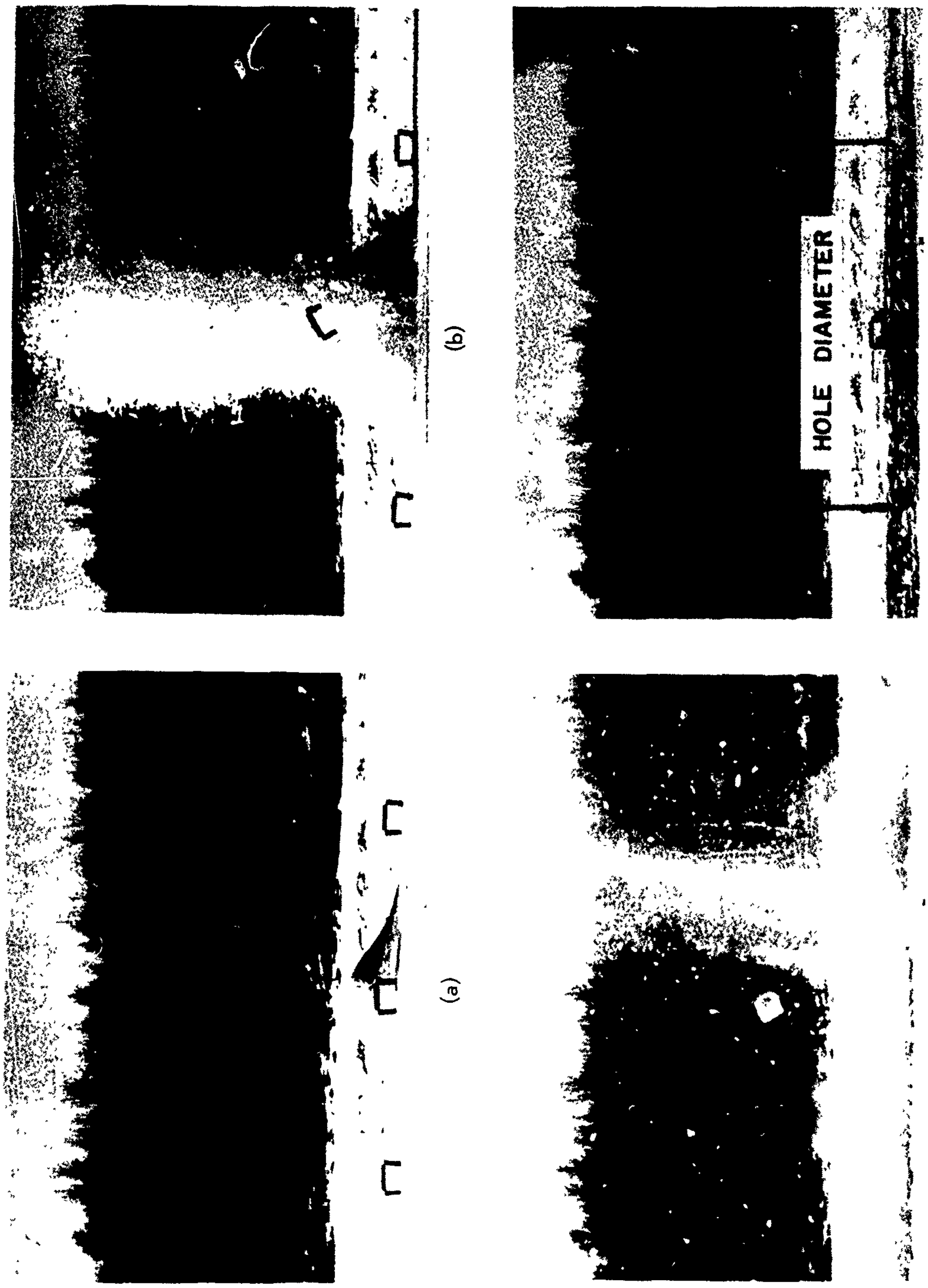

FIG. 1 PHOTOGRAPHIC SEQUENCE: UNDER - ICE EXPLOSION

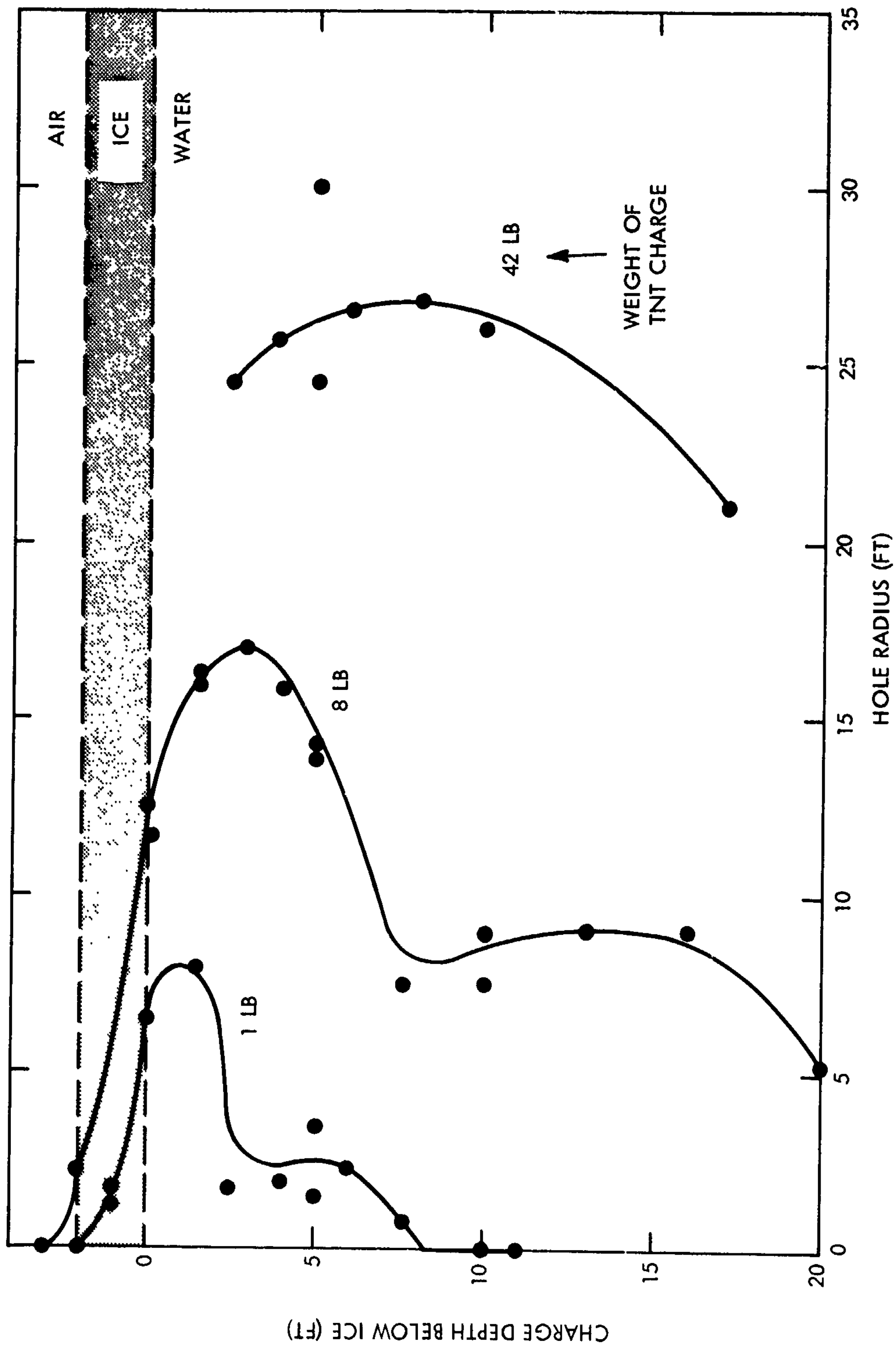

FIG. 2 HOLE RADIUS IN ICE VS CHARGE DEPTH

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